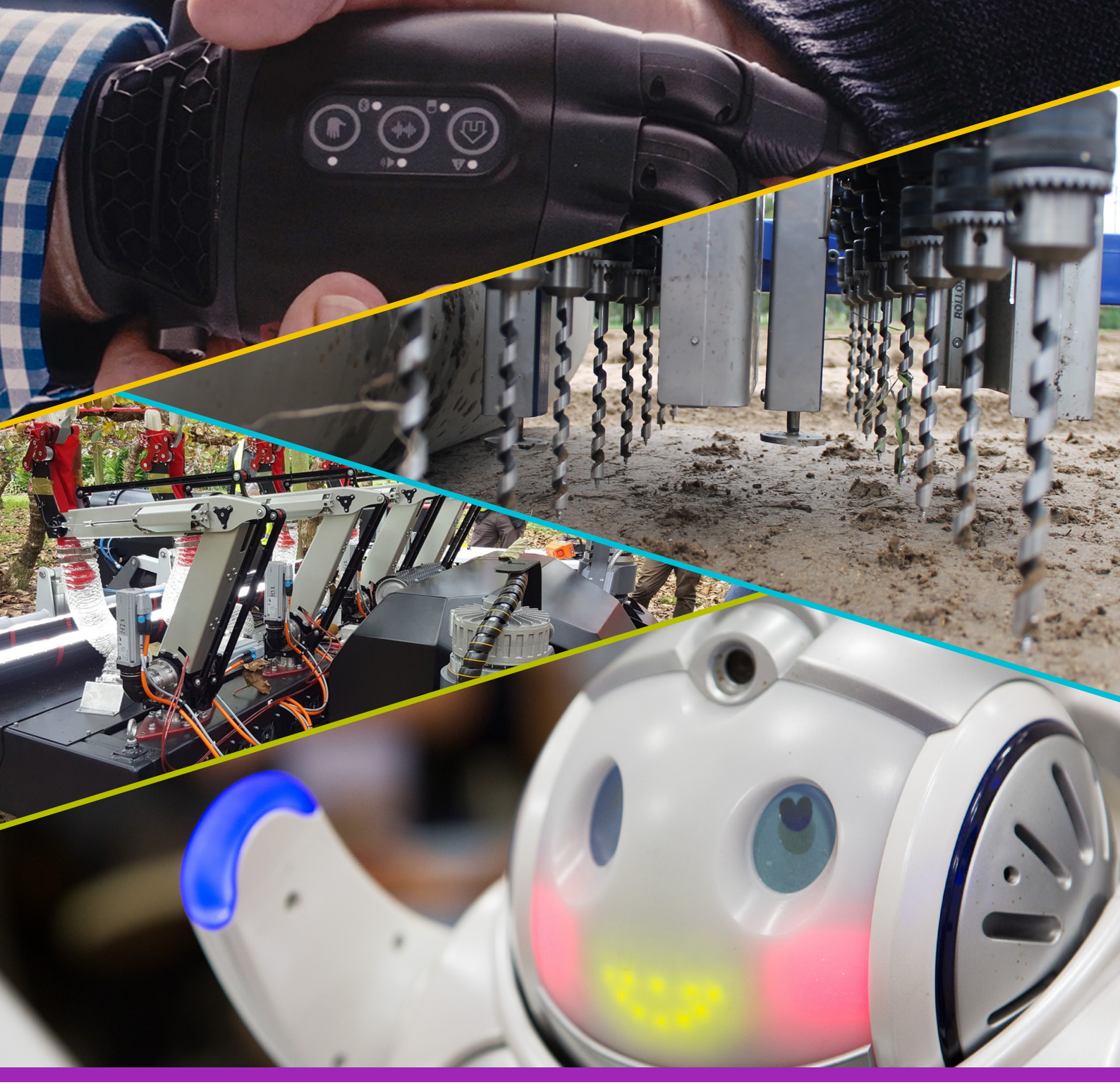

New Zealand Robotics, Automation and Sensing Roadmap

2020/2021

NZRAS
NZ ROBOTICS, AUTOMATION, AND SENSING

www.nzras.org.nz

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INTRODUCTION

New Zealand Robotics, Automation and Sensing (NZRAS) is a network of researchers, engineers, technologists and students involved in the research and application of robotic, automation and sensing technologies across New Zealand.

We aim to bring together everyone in the innovation ecosystem to facilitate the advancement of science and technology. Our members include researchers from tertiary institutions, CRIs, COREs, Callaghan Innovation, and various industry groups in New Zealand. NZRAS intends to foster and build collaborations, partnerships, and networking to undertake research and development projects, in particular those with a national focus, such as the National Science Challenges.

NZRAS organises conferences and other meetings, and serves as a focal point for New Zealand industry and researchers.

This roadmap is the first of its kind, and will act as a benchmark for the development of RAS in New Zealand.

New Zealand's RAS ecosystem has over 84 developers, 43 integrators, and 870 researchers, with over 350 estimated users. It is conservatively estimated that the developer and integrator companies generate more than NZD $1 billion in annual revenue, and employ over 3,200 people.

There is a significant opportunity to create a more cohesive ecosystem, which will drive New Zealand-based RAS company commercial growth and adoption, and increase productivity and wellbeing by using RAS.

THANKS TO OUR COLLABORATORS

EXECUTIVE SUMMARY

New innovative technologies are drastically changing the way we do things, and, as a result, our industries and workforce are changing ten times faster, and at 300 times the scale of the first industrial revolution. A significant cause of this change is the use of Robotics, Automation and Sensing systems (RAS). RAS uptake is increasing globally and rapidly, with up to 46% of current day jobs expected to be at risk of replacement by 2040, as a result of automation, and the number of all types of industrial and service robots used expected to at least double by 2025. Consequently, strategically understanding the challenges and opportunities associated with RAS, and the formation of a common vision, is vital for a country to prosper from these developments.

New Zealand is a well-developed nation, regarded as one of the best places to live in the world. However, due to its small size, and distance from trading partners, it has historically been behind in technological advancements. With regard to RAS, this has meant poor adoption rates, which has led to significantly lower productivity. Although RAS is increasingly mentioned by many government and industry bodies, until now there has been no Roadmap of the New Zealand context presented to strategically guide the development of New Zealand's RAS ecosystem and specific sector developments.

New Zealand's RAS ecosystem has over 84 developers, 43 integrators, and 870 researchers, with an estimated 350+ users. It is conservatively estimated that the developer and integrator companies generate more than NZD $1 billion in annual revenue, and employ over 3,200 people. This indicates that there is a strong RAS industry in New Zealand. However the New Zealand RAS ecosystem appears to be very fragmented, with multiple disconnects across organisations and sectors, leading to potentially duplicated efforts and ineffective collaborations. This fragmentation is likely the result of poor RAS visibility overall, which can lead to poor adoption rates, misinformed public opinions, and poor international investment and collaboration. Therefore a large portion of this roadmap is dedicated to presenting New Zealand's RAS capabilities. There is a significant opportunity to create a more cohesive ecosystem which will drive New Zealand-based RAS company growth and adoption, and increase productivity and wellbeing by using RAS.

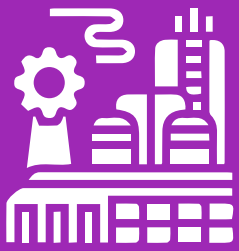
The two main sectors where RAS is integrated and developing are manufacturing (29% of RAS businesses), and services (23% of RAS businesses). Manufacturing largely consists of companies integrating and adapting internationally-developed RAS into mostly international workplaces, and developers creating RAS solutions for the food and beverage sector. Services have a diverse range of focus areas, however unmanned vehicle development(land, air, and sea), and logistics and packaging services (six companies) have been identified as two growth areas. Horticulture, forestry, agriculture, aquaculture, and healthcare are all potentially emerging fields, with each having more than 10 actively growing companies. These developments appear to be largely driven by labour shortages, and the need for safer and more consistent practices. Lastly, in each sector, unique challenges to developing RAS were identified, particularly around the environment in which RAS must operate, the culture of potential end-users, and the sector business models used.

General interest in RAS is slowly growing, with the increase in RAS-qualified people outpacing other engineering disciplines (300% over the past decade), and the Government has begun to implement initiatives directly supporting RAS development, such as the proposed horticulture technology catalyst. However, industry demand for RAS-qualified people and support is higher than availability, leading many companies to look at international companies instead. Similarly, the commercialisation and growth stages of New Zealand's RAS companies are poorly guided, and

EXECUTIVE SUMMARY

46%

of current day jobs expected to be augmented by 2040



Workforce are changing ten times faster and at **300 times** the scale of the first industrial revolution

made more difficult through limited access to Venture Capital (VC) funding.

In addition the regulations currently in place are well set up for testing new RAS, but significantly limit the ability for commercial systems — specifically regarding Unmanned Ground Vehicles (UGVs) and Unmanned Aerial Vehicles (UAVs) — to be used, requiring more active government revision of regulations. It appears that RAS is generally accepted by the general public and industry, but many still do not understand its capabilities and potential use in society.

More than 70 active RAS researchers were identified in New Zealand, with many focused on applications around agriculture, forestry, and healthcare. The top fundamental research area was based on vision and sensor control. This is a strength that can be applied across a range of different sectors, particularly those with complex, unstructured environments, as seen in horticulture, healthcare and agriculture. However, the current KPIs for New Zealand-based researchers restricts researcher's time, and discourages commercialisation and industry collaboration. In addition, limited funding regimes currently fall short of funding a research project to a stage where a commercially viable product is created.

There is poor diversity of gender and ethnicity in RAS, with gender diversity reflecting the same unequal balance seen in all STEM fields. Racial diversity appears to be stronger, with many people of Asian and Indian ethnicity involved, but there are very few Māori and Pasifika people represented. This opens up a great opportunity to identify and use Māori knowledge and systems to develop more sustainable RAS solutions.

COVID-19 has presented many challenges and also many opportunities for RAS developers. In particular, the drive for improved food security and unmanned remote operation could increase RAS uptake and support. In addition, current restrictions on international travel supports the need to improve New Zealand's capability, and reduce dependence on international access to seasonal labour.

Australia has an active RAS ecosystem, having formed two different RAS roadmaps, strategically planning RAS developments. A workshop was held to determine how collaboration could enhance both nations' RAS endeavours. From this one of the key directions was to create a network to improve our overall scale and international connectivity.

Overall, New Zealand has a significant opportunity to become a world leader in specific areas of RAS development, in the horticulture, forestry, agriculture, aquaculture, and professional services (particularly UAV usage) sectors. These are well supported by research and industry presence. A secondary area would include construction and healthcare, but these require greater research support than is currently available. However, to realise these opportunities, there need to be significant changes in government, industry, and research practices.

Dr Kent Stewart

CONTRIBUTORS

This roadmap was created from research conducted by Dr Kent Stewart.

Dr Stewart is a early career researcher in RAS, who is keen on seeing the benefits of such technology used. His prior works have focused on modelling, controls, and sensor design in the healthcare sector. Future works will focus on using the knowledge gained to improve RAS developments in New Zealand.

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***Rocos** for providing connections to experienced US-based RAS ecosystem developers and investors.*

***Sue Keay**, **Andrew Scott**, and **Hanna Kurniawati** for organising the Australasia Collaboration workshop and providing insights into the development of RAS in Australia.*

ROADMAP PURPOSE

This Roadmap presents a shared vision of New Zealand's Robotics, Automation and Sensing systems (RAS) strategic priorities and capability needs.

Internationally, RAS is becoming readily adopted as the technology and potential applications advances. As a result, many countries have put in place strategies in order to align their nations vision and direction of RAS development. This Roadmap acts as New Zealand's first strategic plan around RAS development, outlining the challenges and opportunities of developing RAS in New Zealand, and forming a common vision for the future.

In-depth consultation with over 35 RAS stakeholders (industry, government, and research) identified a currently fragmented ecosystem and quantifying the presence, skill capability, government support, culture, and diversity around RAS in New Zealand. Combined with the review of New Zealand government and industry body reports, recommendations are made on the capability and areas for growth around the development, commercialisation, and adoption of RAS in New Zealand.

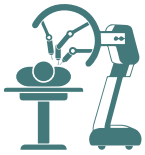
This roadmap investigates all major sectors of New Zealand which may benefit from RAS development, allowing the current state and potential opportunities within New Zealand to be understood. An outline of the unique advantages, currently supported initiatives, future opportunities and direction of RAS in each sector are provided.

Note, aerospace and defence were considered out of the scope of this roadmap.

WHAT IS RAS?

Robotics, Automation, and Sensing systems (RAS) encompass multiple sub-disciplines and technologies to provide the ability for robotic and/or automated systems to perform tasks without human intervention.

The common drivers for RAS adoption across all sectors are generally to increase productivity, improve product or service quality consistency, and/or improve health and safety. New innovative technologies are drastically changing the way we do things, and, as a result, our industries and workforce are changing ten times faster and at 300 times the scale of the first industrial revolution.

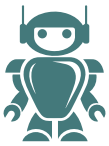


MEDICAL ASSISTANCE

Surgical assistance, medical diagnosis, and patient assistance

UNMANNED AERIAL VEHICLE (UAV)

Aerial surveying, product delivery, surveillance, filming



HUMAN ASSISTANCE

Cleaning robots, automated hospitality

EXOSKELETON

Rehabilitation of limbs or assistance in movement

UNMANNED UNDERWATER VEHICLE (UUV)

Underwater welding, surveying, and inspection

HUMANOID

Rehabilitation robots, elderly care companion robots

PROSTHETICS

Replacement of functionality of missing limb

UNMANNED GROUND VEHICLE (UGV)

Self-driving cars, land surveying, product delivery

SORTING AND PACKAGING

Sorting, packaging, and assessment of items

AUTOMATION LINES

Factory assembly lines, raw to finished product refining

ROBOTIC ARMS

Large payload movement, assembly and welding

WAREHOUSE MANAGEMENT

Sorting and management of stack and/or packages

WHY DOES NEW ZEALAND NEED RAS?

New Zealand itself is a well-developed nation, regarded as one of the best places to live in the world. However, due to its small size and distance from trading partners, it has historically been behind in technological advancements.

RAS uptake is increasing globally and rapidly with up to 46% of current day jobs expected to be at risk of replacement by 2040 as a result of automation, and the number of all types of industrial and service robots used expected to at least double by 2025.

The New Zealand economy

Over 70% of New Zealand's annual Gross Domestic Product (GDP) either currently or could, in the future, be influenced by the adoption of RAS.

Based on 2018 figures, New Zealand's economy is currently driven by three main sectors; manufacturing (11% GDP), tourism (9.8% GDP), and professional services (8.7% GDP). New Zealand is a country with a relatively small domestic market but with comparatively good primary production, so New Zealand is very dependent on the trade of goods and services, with exports accounting for over 27% of GDP.

Increase New Zealand's low productivity growth

Over the past two decades New Zealand's Gross Domestic Product (GDP) per capita is, on average, 9.4% lower than the OECD average. New Zealand's GDP per hour worked has grown 17% slower than the OECD average. New Zealand's overall productivity is 20% lower than the OECD average and is likely the result of poor technology adoption.

New Zealand's low labour productivity growth has resulted in both slow overall productivity growth and reduced international investment in New Zealand. In order to compete in the international market many New Zealand companies need to innovate to increase productivity.

It is conservatively estimated that over 350 companies in New Zealand use some form of RAS to aid them in offering a product or service.

Note: the number of companies who use RAS was only able to be estimated based on correspondence with developers and integrators, as users typically do not publicly state their usage of RAS.

WHY DOES NEW ZEALAND NEED RAS?

Retain talent and compete on the world stage

RAS enables local companies to be more competitive in the international market and less likely to relocate. Localisation of companies brings a multitude of benefits for the local economy, and helps attract and expand talent for local developers, increasing the overall international competitiveness of the nation.

As technology in general is developing rapidly, changing the context of many industries, New Zealand has started to develop strategies of development within the New Zealand environment. However, there appears to be no current strategy around RAS developments in New Zealand. Additionally, from an assessment of the maturity of RAS in New Zealand, and globally, it is clear there are many sectors which can still benefit from greater RAS development.

The industry demand for RAS-qualified individuals and support is still significantly higher than what is currently available in New Zealand, leading many companies to shift to international support mechanisms.

Similarly, many New Zealand developers also look to international markets for early adoption of their technology, as there are the financial resources and understanding to adopt RAS more easily. Once the technology is proven internationally the locally-based end-user may then investigate the adoption of the technology, but this limits any potential competitive advantage gained from early adoption.

Overall, this convoluted staging of adoption is very inefficient in terms of resources, capital, and workflow interruptions, and should be a focus area for industry in the future.

The vast majority of RAS technology currently used in New Zealand is imported from international suppliers, determining the pace of technological change here. This is not unsurprising due to the competitive prices and quality that large international firms can provide compared to domestic firms.

Upskilling our current workforce to equip them for the future of work

As a result of the rapid advancements in RAS technology, many current industry employees across the world do not understand new RAS technologies.

Upskilling current staff and improving education systems so individuals are able to use and maintain new RAS-related technology has become a key focus area of some countries including South Korea, and Australia.

This training ensures new RAS technology can be used effectively and the maximum benefits reaped. Globally, CEOs are identifying that finding talent is becoming more difficult than upskilling current employees, with 84% planning to upskill employees by 2020.

Limited financial resources affect RAS investment

99% of New Zealand businesses have fewer than 50 employees and 97% have less than 20.

New Zealand businesses typically have limited financial resources and experience with RAS. As a result, they take a very conservative approach to the adoption of RAS. Larger businesses typically have the financial resources, business processes and experience to invest in R&D and manage potential new RAS, and the associated risks. Studies showing that the adoption rate of industrial robots was almost directly proportional to the company size. The overall adoption rate of RAS in New Zealand is significantly challenged by the typical size of New Zealand businesses.

Within New Zealand's small and medium-sized enterprises (SME) environment RAS is typically only retrofitted into existing workflows, and only performs a small section of the overall process to limit associated risk. In some cases, this is due to the RAS technology not being capable of performing all the required tasks. In many cases the RAS technology is very capable, but the required investment to extend its range is perceived as too large or has a high associated risk.

Similarly, commercialisation and growth stages of RAS companies in New Zealand is poorly guided, and is further made difficult through the limited venture capital (VC) funding available. The current regulations in place in NZ are well set up for testing of new RAS, but still significantly limits the ability for a commercial system to be used, specifically around Unmanned Ground Vehicles (UGVs) and Unmanned Aerial Vehicles (UAVs) and need more active government revision.

Many end-users still prefer to buy locally assembled, turn-key RAS solutions, if possible, providing them with domestic service support and supporting local businesses.

WHAT IS NEW ZEALAND'S CURRENT RAS CAPABILITY?

New Zealand Ecosystem

New Zealand's RAS ecosystem has over 84 developers, 43 integrators, and 70 RAS researchers, and an estimated 350+ users.

It is conservatively estimated that the developer and integrator companies generate more than NZD $1.1 billion in annual revenue and employ over 3,200 individuals.

Therefore, there is a strong presence of the RAS industry in New Zealand.

However, the New Zealand RAS ecosystem appears to be very fragmented, with multiple disconnects across organisations and sectors, leading to potential duplication of efforts and ineffective collaborations. This fragmentation is likely the result of poor overall RAS visibility, which leads to low adoption rates, misinformed public opinions, and poor international investment and collaboration. A large portion of this roadmap is dedicated to presenting the capabilities of RAS in New Zealand.

NZ Robotics and Automation Systems (RAS) Ecosystem

*Organisations in the process of being formed

**NZ Tech Alliance communities include Agritech NZ, AI Forum, BioTechNZ, BlockchainNZ, Canterbury Tech Cluster, Digital Identity NZ, EdTechNZ, InsurTechNZ, LocationTechNZ, ManawaTech, NZHIT, NZ IoT Alliance, NZGDA, NZ Hi-Tech Awards, NZTech, ShadowTech, Tech Marketers Group, Tech21, TechLeaders Executive, Technology Valley Forum, Techweek, TechWomen, WealthTechNZ.

PUBLIC PERCEPTION OF RAS IN NEW ZEALAND

The general interest in RAS is slowly growing in New Zealand, with the number of RAS-qualified individuals outpacing other engineering disciplines (300% growth over the past decade), and the government establishing some initiatives directly supporting RAS development. Socially, it appears the general public and industry are more accepting of RAS. Many New Zealanders still do not understand the capabilities of RAS and do not believe it is useful for society.

Creating the right culture around RAS is very important to the development and adoption of the technology. Being a small economy located at the bottom of the world, New Zealand does not always get sufficient exposure to modern technological innovations. As a result, the New Zealand public may rely on sensationalized media releases to inform them of global RAS developments. This ultimately results in a very mixed culture around RAS technology, and its development and usage.

It is expected that by 2030, 35% of physical labour and manual dexterity jobs — such as those seen in transportation and storage, manufacturing, and construction — will be replaced by automated systems. These statistics inevitably create concerns about robots 'stealing' people's jobs, and although at first glance this appears to be true, further analysis has shown this to not be the case.

As a result of the adoption of RAS a company's productivity will likely increase, and consequently the labour which was once required for the repetitive manual tasks are now required in more complex tasked areas of the business.

Limited exposure and understanding of RAS

From consultation with industry, it appears potential end-users of RAS are still rather unfamiliar and lack understanding of the potential benefits and capabilities of RAS. As a result, there is an increased perceived risk around RAS which leads to lower adoption of such technology in the workplace. This is improving as more businesses begin to adopt RAS, but New Zealand is still very much behind relative to international adoption rates. There is a need to show potential end-users the capabilities of RAS in real-world applications.

Currently in New Zealand there is no single organisation which promotes the benefits and potential capabilities of RAS to students, businesses, and the general public. As a result, the messages around RAS are mixed and weak. There is an opportunity for a single organisation to promote the benefits and potential capabilities of RAS. This promotion will then lead to improved interest and visibility of RAS, and feed into better RAS developments and adoption in New Zealand.

GLOBAL TRENDS

With advances in Artificial Intelligence (AI) out-performing human capabilities, it is expected that the automation of physical tasks will grow by

30%

between 2025-2038

Previous RAS systems were largely bulky, expensive, inflexible, and designed for physically difficult and/or dangerous tasks such as heavy lifting, welding, and painting. Now such systems are becoming more advanced, with increased dexterity, intelligence, and sensing capabilities. In addition, they are also becoming more compact and adaptable to different environments.

Globally the number of RAS systems used is increasing rapidly, with over 420,000 industrial robots and 16.3 million domestic service robots being installed or used annually, and growing.

The significant global growth into RAS started in 2010 and has grown at an annual rate of 19% per year between 2013 and 2018. This is significant given that, at present, the total number of industrial robot arms installed globally is estimated to be more than 50% of New Zealand's current population of 5 million.

As RAS systems are becoming more developed, and the competition between the systems and parts suppliers is increasing, the price of such technology is rapidly decreasing. As an example, the price of the sensors used in autonomous cars has gone from NZD $350,000 to NZD $1,000 in the past decade.

KEY SECTORS THAT WILL BENEFIT FROM RAS DEVELOPMENT

Based on the supporting initiatives, challenges, research backing, and current industry presence identified, it appears that most opportunities lie within manufacturing, horticulture and forestry, agriculture and aquaculture, and professional services (particularly UAV) usage.

Other sectors, such as construction and healthcare, also have considerable potential because of New Zealand's RAS research presence, the ability to provide local support, and the size and demands of the domestic sector currently. For these opportunities to be best realised significant changes in government, industry, and research practices need to occur.

Note: The key sectors bolded statistics to be presented visually to give a quick, simplistic breakdown of the current position and value of the sector.

AGRICULTURE AND AQUACULTURE

Note: All GDP stats are from 2018.

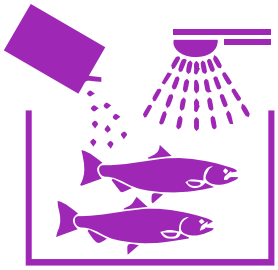
Agriculture is a significant contributor to New Zealand's annual GDP with over 39,700 livestock farms accounting for over 4.3% (NZD $12.4 billion) of the annual GDP in 2018. Additionally, Aquaculture contributed NZD $15.1 million (0.4%) to New Zealand's 2017 GDP and employs over 14,700 people.

Both areas receive the majority of their revenue from exported goods such as milk powder, meat, seafood, and wool, and contributed to over 65% of New Zealand's primary sector exports in 2018.

Agriculture is accounting for over

4.3%

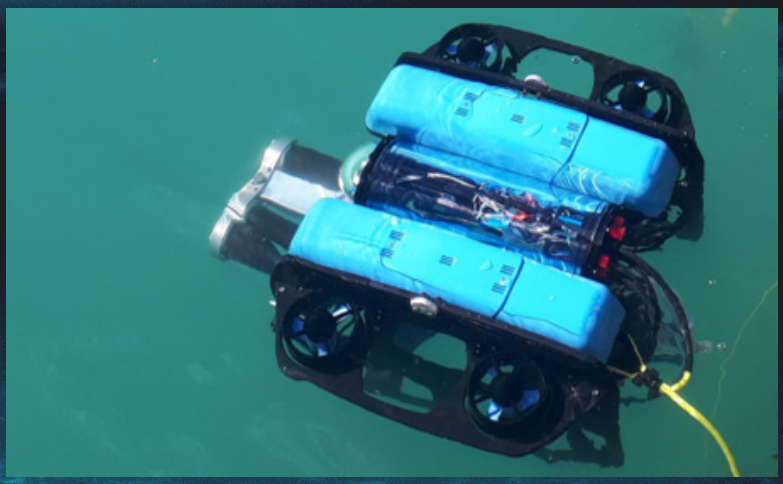
of the annual GDP in 2018



Aquaculture contributed

0.4%

to New Zealand's 2017 GDP



Sector Advantages

- The number of potential areas with varying environmental and geographic conditions for robust testing of the technology.
- Relatively large size of the domestic market for initial testing and potential support when growing a company.
- The agricultural sector is familiar with health and safety hazard management.

Sector Challenges

- The individual developing the RAS may not necessarily have the expertise required to develop the product, or understand the end-user's needs and abilities. This creates a 'solution looking for a problem' situation where the value proposition is unclear.
- Practices in New Zealand (e.g. the rotary milking shed) are different to international practices. Milking accounts for 50% of hours worked on a dairy farm. Automated Milking Systems (AMS) are commercially available, but they are too expensive and not necessarily ideal for New Zealand pasture-based milking practices.
- Farm owners typically rely on peers for information on whether a new technology could be beneficial rather than experts, prolonging the adoption rate.
- The common business model of farming in New Zealand typically results in many farmers having significant amounts of capital locked in assets/debt which reduces their desire and/or ability for future investment (particularly in meat, wool, and dairy).
- Limited access to testing facilities to ensure a robust RAS is developed. Products end up going to market before being suitably assessed.
- Uncertainty about the actual benefits of the RAS. The benefits need to be expressed in terms of economics relevant to farmers e.g. cost per kg of milk solids. This is exacerbated by the lack of access to testing facilities and resources to determine these values.
- A number of different technology systems are available, but do not allow for cross platform communication, and do not complement each other. Ultimately, this results in lower productivity due to the work required to overcome compatibility barriers. Data standards are commonly disregarded in favour of individual approaches.
- Network connectivity and cellular coverage on farms is limited.
- Staff lack motivation and resign, resulting in a high turnover rate. For new technologies this potential means having to retrain staff on specific products.

Currently, these challenges have resulted in less than 3% uptake of RAS in New Zealand farming, and limited international success. In particular, the lack of applicability to international markets, given the large differences in farming, has limited the international demand for New Zealand-focused agricultural RAS solutions.

Predicted RAS direction within Agriculture and Aquaculture over the next 5-20 years

	0-5 Years	5-10 Years	10-20 Years
Livestock	• Real-time personalised livestock performance monitoring. • Smart livestock monitoring for disease and sickness.	• Herd logistics automation based on personalised livestock performance • Improved milking plant automation inc. real-time sensor data • Automated shed maintenance systems (e.g. cleaning) • Assistive milking systems • Assisted sheep shearing	• Accessible and Serviceable Automated milking systems • Automated sheep shearing • Automated farm logistics and monitoring, • Changed scope of requirements for farmer. • Hands free animal management
Pasture management	• Handheld pasture monitoring systems. • More efficient pasture maintenance (e.g. smart fertiliser application).	• UAV and UGV farm monitoring systems (e.g. remote farm walk) • Semi-automated pasture maintenance and management	• Fully automated farm monitoring. • Fully automated pasture maintenance
Aquaculture	• Improved digitalised capture of aquaculture farm dynamics	• Remote aquaculture farm monitoring • Semi automated aquaculture farm maintenance	• Fully automate commercial fishing vessels with only supervisors needed

HORTICULTURE AND FORESTRY

The number of exports is growing significantly for the horticulture and forestry sectors with the demand for fruit and vegetables in New Zealand expected to be 33% higher by 2043.

Both sectors are facing many challenges; some are looking to robotics to solve issues around labour shortages, more efficient water use, and intensive farming. The multitude of initiatives and unique advantages of developing RAS around horticulture and forestry provides a good foundation for RAS growth. Several challenges identified earlier are still constraining some development and adoption of RAS, and need to be addressed.

In 2019, horticulture produce accounted for an estimated NZD $9.5 billion in revenue, with over 65% (NZD$6.2 billion) of this coming from export revenue (10% of New Zealand's total exports).

Similarly, New Zealand's forest industry provided NZD $6.8 billion in export revenue and NZD $3.5 billion in GDP. Overall, horticulture and forestry plots cover 1.89 million hectares of New Zealand land (7% of total), with horticulture providing the highest export value per hectare of all New Zealand exports types (NZD$32,158/ha/year).

Both sectors are strongly export focused with forestry exporting over NZD $3.8 billion worth of logs, and horticulture exporting over NZD $4.9 billion of produce in kiwifruit (NZD $2.3 billion), wine (NZD $1.8 billion), and apples and pears (NZD $0.8 billion) in 2019. Both sectors are considerably influenced by global competition.

Sector Advantages

- A number of potential areas with varying environmental and geographic conditions for robust testing of the technology.
- The large number of growers and forestry plots across New Zealand should provide a sustainable domestic market for RAS company growth.

Sector Challenges

- Limited access to testing facilities to ensure robust RAS is developed. Products go to market before being suitably assessed.
- Uncertainty about the reliability and actual benefits of the RAS. The lack of access to testing facilities to robustly test and prove RAS further worsens this.
- Climate change is expected to reduce soil productivity, potentially reducing the yields from horticulture and forestry, reducing the amount of capital able to be invested in RAS per hectare of land.
- High turnover of staff means a significant amount of training is required. Any RAS implemented which a user must operate must require minimal training. Similarly, the digital literacy, data management and analysis skills of staff need to improve to increase potential RAS adoption.
- As New Zealand forestry is strongly export focused, it is also strongly influenced by practices in other countries. RAS methods may need to be adopted internationally before being adopted in New Zealand.
- Regional infrastructure, such as electricity grid capacity and lack of reliable data connectivity, constrain the use of some technology.
- Uncertainty of product supply, labour, and transport costs limit certainty of investment into new technology.
- The common business model of growers in New Zealand typically results in having significant amounts of capital locked in assets which reduces their desire and/or ability for future investment.
- Forests are harvested by small contractors (6-10 employees) who don't typically have the money to invest in new RAS.
- Organic structures such as leaves and pine needles attenuate radio frequency signals, making wireless RAS communication and positioning potentially difficult.
- Environment is tough with varying weather conditions, terrain (e.g. mud and tree branches, and gum etc.). New Zealand's forestry terrain is uniquely very hilly, and compressed ground may prevent future plant growth.
- Remote forestry locations mean systems that break down need to be able to be fixed and refuelled easily. Ideally machines could be airlifted out with a small helicopter if needed.
- Understanding the ramifications of working with heavy machinery, as seen in the forestry sector, is not common knowledge for many RAS researchers and developers.
- When operating in the forest environment, there is a need to be conscious about sparks from electrical equipment potentially causing forest fires.

Predicted RAS direction within Horticulture and Forestry over the next 5-20 years

	0-5 Years	5-10 Years	10-20 Years
Horticulture	• Improved sensing systems for harvested crop quality assessment • Cold stores and storage monitoring for defects Improved surveillance of crops through smart sensors • Assistive crop pruning, thinning, and harvesting (work alongside) • Assisted harvest crop selection • Automated weed spraying and control	• Automated monitoring of Packhouses with supervisor • Storage warehousing assistive UGV • Assistive crop seeding, planting and maintenance (more efficient resource usage) • Automated pruning and thinning • Automated smart an selective crop harvesting (choosing the right fruit at the right time) • Improved consumer support for produce brought online (e.g. fruit quality index)	• Lights out packhouse automation • Automated cold storage logistics • Full nursery automation. • Fully automated crop planting and maintenance (Pesticide free) • 24/7 robotic feet harvesting • Supermarket display of quality indices
Forestry	• Assisted tree planting • Autonomous tree surveillance • Remote controlled tree harvesting (particularly on hillside) • Semi-autonomous hillside log collection • Providing cutting automation 10 existing auto assessment tools	• Semi-autonomous tree planting • Semi-autonomous tree thinning and harvesting	• Fully automated tree planting and harvesting able to operating for longer hours (e.g. at night) • Many small (affordable - $100 000) fully autonomous robots used together to harvest the forest.

MANUFACTURING

The adoption of RAS across the manufacturing sector in New Zealand is relatively high, but SMEs and areas of more complex manufacturing still have significant room for growth. The future of RAS in the manufacturing sector in New Zealand will likely be around improving the accessibility of RAS to SMEs, through increased RAS task flexibility, and further adapting more complex RAS methods to the more complex manufacturing environments.

Manufacturing in New Zealand is made up of seven key sub sectors:

1	2	3	4	5	6	7
Food and beverage	Wood and paper	Machinery and equipment	Chemicals and refining	Plastics and rubber	Metals and metal products	Other manufacturing*

*Textiles, leather, clothing and footwear, printing, non-metallic mineral products, furniture, and other manufacturing

The largest sub sector is food and beverage, accounting for 32% (NZD$ 7.4 billion GDP) of all manufacturing output.

The food and beverage sector is strongly driven by the primary industries' drive to create value in their exports. The top three manufacturing exports are milk powder (18%), meat (17%), and butter (8%). Within the manufacturing sectors, meat processing employs the most people (over 30,000 employees), followed by dairy (12,200 employees), structural metal (12,500 employees), polymer plastics (10,900 employees), and bakery (10,700).

Overall, manufacturing employees make up around 11% of New Zealand's national workforce, with approximately 50% employed by large firms (>100 employees).

Sector Advantages

- A relatively large number of domestic food and beverage manufacturers to support initial testing and growth into an international market.
- Approximately 20% of all manufacturing firms undertake some form of R&D annually, over 25% in food and beverage, and 45% in high technology manufacturing. This is also likely a result of the firm sizes being larger and having more resources to invest in R&D.
- Manufacturing firms have higher rates of investment by foreign firms, and are more likely to have overseas investments themselves, than the New Zealand average. They typically have strong ties to the international market.

Sector Challenges

- Manufacturing SMEs have limited resources for RAS uptake. Flexible and adaptable RAS methods may be required.
- There is poor visibility of New Zealand's current RAS research and international business capabilities, which could be applied to the more obscure manufacturing subsectors.
- Many global competitors in this more mature area of RAS can make it difficult to compete internationally with companies coming from economies of much larger scale. New Zealand manufacturing RAS companies require an early international presence.

Predicted RAS direction within Manufacturing over the next 5-20 years

	0-5 Years	5-10 Years	10-20 Years
SME manufacturing	• Multi-task (2-3) RAS systems which are able to be changed through both minor manual and software interventions. • Cobots working in parallel with humans. • Robots learning through manual guidance of initial procedure.	• Task adaptable RAS through only simple software interventions (covering all tasks). • Humans working with cobots to complete a task e.g. helping each other.	• RAS smart interpretation of the required task and self-adjusts to required tool set. • Human helper robots which can interpret the needs of a human for a specific task. • Task learning robots (e.g. show and tell) thus requiring no programming.
Food and beverage	• Semi-autonomous meat processing. • Seri-autonomous fish and selfish processing. • Assisted bakery goods processing.	• Fully autonomous meat processing with only minimal human assistance (e.g. humans do not perform cutting). • Fully autonomous fish, shellfish, and bakery goods processing.	• Completely automated meat processing with only plant supervisors.

CONSUMER AND PROFESSIONAL SERVICES

Within New Zealand the retail trade generates over NZD $96 billion in sales, with the three largest sectors being supermarkets (21.4%), motor vehicle and parts retail (13.7%), and food and beverage services (12.3%). In 2018 the retail trade generated almost NZD $13 billion in GDP, and employed over 219,000 people annually. Similarly, wholesale trade generated over NZD $14.2 billion in GDP, and employed over 114,400 people.

To support this wholesale and retail trade a strong transport, postal, and warehousing system is required. In 2019, transport, postal, and warehousing employed over 99,900 people. This contributed to over NZD $13 billion in annual GDP.

The number of trucks registered on New Zealand roads increased by 50% from 2010 to 2020, now totalling over 645,000. Similarly, the number of taxis registered over this same period increased by 134%, with currently over 17,900 registered.

New Zealand has some niche developing companies in the services sector, which could create some world-leading RAS developments, particularly around UGVs, logistics and packaging.

As the population of New Zealand is growing the consumer demand for services and professional services is also growing. Technology around UAVs is becoming more prevalent and cheaper across the globe, and, as a result, the number of operators is growing. Currently, there are a considerable number of consumer drones and over 125 industrial UAVs (based on the number of registered Part 102 operators) used in New Zealand. These numbers are growing considerably as the capabilities and potential applications of UAVs grow.

Consumer and professional services are typically strongly targeted towards the customer's needs and improving delivery of a product or service for a customer. This generally includes improving the efficiency and quality of the product or service offered. In the past decade there has been a strong shift towards remote services, particularly driven by COVID-19.

Sector Advantages

- New Zealand has a small domestic retail and wholesale trade market, ideal for testing new RAS products before going to the international market.
- New Zealand regulatory authorities are generally adaptable to allowing testing of new RAS in New Zealand, particularly for UGVs and UAVs.

Sector Challenges

- Consumer RAS must acquire a significant social license before the average citizen is comfortable with it and adoption is widespread. Privacy concerns must also be considered.
- The regulations around integration of unmanned vehicles into civilian airspace and roads are still relatively constricting and restrict beyond line-of-sight usage. Apart from testing, there is little justification for providing a management infrastructure for such technology.
- Cellular coverage is not ensured, limiting reliability of RAS tracking.
- A small economy means goods and services are typically more expensive.

Predicted RAS direction within Consumer and Professional Services over the next 5-20 years

	0-5 Years	5-10 Years	10-20 Years
Consumer	• Supervised completely autonomous unmanned vehicle usage	• BLOS UAV usage in rural areas • Accommodation and tourism services being partially serviced by robots • Unsupervised unmanned vehicle/RAS usage	• BLOS UAV usage in urban areas such as UV delivery • Accommodation and tourism services being fully serviced by robots
Professional	• Fully autonomous UGV for warehousing • Self-driving minibuses (UGV) for short distance public transport	• Fully automated airport logistics around freight and handling baggage (exec airport tarmac activity) • Fully automated utilities management	• Fully automated packaging sorting and delivery of freight • Fully automated airport logistics (inc. airport tarmac activity etc.) • Fully autonomous public transport buses

CONSTRUCTION AND INFRASTRUCTURE

Construction and infrastructure are a vital part of the global economy as the world's population grows. The construction sector in New Zealand is the fourth largest sector contributing over 7% of our annual GDP, and is expected to grow by 10% between 2019 and 2021. The construction sector currently employs 275,000 people — almost 10% of New Zealand's total workforce.

A considerable amount of this growth is attributed to the 39% growth expected between 2018 and 2025 in the Auckland construction sector. The overall growth in this sector is expected to peak in 2021 at a total of NZD $43 billion.

In 2018, approximately NZD $22 billion was spent on residential construction, NZD $9 billion was spent on non-residential construction, and NZD $8 billion on infrastructure, leading to over 20,000 detached dwellings, 6,000 townhouses, 4,000 apartments, and 2,000 retirement homes consented. The New Zealand Government also has a NZD $5.6 billion initiative to construct over 1,000 state houses a year.

Sector Advantages

- New Zealand's relatively large domestic market size to support company growth while expanding to the international market.
- Government drive to increase state housing in an attempt to stabilise the housing market.

Sector Challenges

- Poor innovation rates and low adoption rates of new technologies in construction. This includes modern methods of construction such as prefabrication.
- Limited collaboration or knowledge sharing of new methods, likely as a result of distrust, in a sector which consists of multiple small organisations.
- Poor risk and business management which leads to low margins and low productivity. Consequently, this leads to a high business failure rate with only 23% of the construction firms established in 2009 still trading in 2019.
- Regulations are not necessarily clear and are not consistently applied. 69 different consenting authorities exist across New Zealand, which leads to inconsistent regional consenting processes. This may result in it being difficult for new RAS to be commercially viable while adhering to the regulations
- New Zealand's standard building practices are not necessarily representative of international practices. The adoption of international methods and materials add potential extra work and costs in terms of consents and structural reworking.

Predicted RAS direction within Construction and Infrastructure over the next 5-20 years

	0-5 Years	5-10 Years	10-20 Years
Infrastructure	• AI assistance in fault detection.	• Semi-autonomous infrastructure scans.	• Fully automated infrastructure scans which are used in standards and regulations.
Construction	• Digitisation of the Construction and panning process (e.g. detailed CAD models of structures). • AR site surveillance assistance. • Automated manufacturing of modular parts used in structures assembly. • Structural analysis using detailed CAD models. • Automation of relatively simple processes such as concrete cutting and assembly.	• Semi-automated/assisted assembly of modular components off-site in a warehouse. • Flexible and automated structure design and manufacture. • Site surveillance using person as the carrier of the equipment. • Building codes and practices changed to accommodate automation methods.	• Maximised off-site automated assembly of structure modules in a warehouse. • On-site automated site inspection and logistics using a form of unmanned vehicles. • Exoskeletons to support heavy lifting and support workers.

HEALTHCARE

The New Zealand healthcare system is currently made up of 83 public and 74 private hospitals, which provide 10,665 and 1,819 patient beds, respectively. In 2010, 83.2% of total health expenditure was from publicly funded institutes.

In 2013, New Zealand spent 9.5% of its GDP on health equating to USD $3,328 per capita, slightly below the OECD average of USD $3,453. This shows that New Zealand has a publicly funded healthcare system with relatively acceptable funding. Overall, the healthcare system employs over 52,000 nurses, 14,000 doctors, 2,000 dentists and 3,000 midwives.

These healthcare workers are spread across hospitals, general practices, rest homes, and other clinics in New Zealand. New Zealand also has a strong research capability and some good supporting initiatives which could enable successful RAS developments in this space.

Sector Advantages

- New Zealand has a strong biosensor and modelling background based on the research groups and companies in the Medtech core. There is a strong foundation for acting robustly on sensor data with RAS implementations.
- New Zealand's HealthTech sector currently generates NZD $1.9 billion in annual revenue and has been growing by 9.1% compound annual growth rate in the past five years.
- The registration process for medical devices is relatively simple, using the MedSafe/Pharmac register.

Sector Challenges

- The individual developing the RAS may not fully understand the problem to be solved. As a result, the needs and abilities of the end-user are not properly considered, and the value proposition may be incorrectly aligned. Access to clinician time to determine the correct developments may be difficult because clinicians are typically overworked.
- The age of healthcare workers is becoming significantly older (particularly at a more senior level) with over 40% of all doctors, nurses and midwives aged over 50 years. Although this experience is useful for understanding new situations, it may hinder technology adoption due to a preference for traditional practices. The result is a very slow adoption of technology.
- Digital literacy of clinicians is low and further impedes adoption. This likely is further contributed to by an older workforce.
- The funding system for new technology (particularly in the public sector) is complex and variable. A product needs to have the correct value proposition, timing to market and funding policy for it to be adopted. This is not always suitable for the developing company. It is recommended that all developers in this space consult a health economist to understand this better.
- Even if patients want to use the technology, clinicians and funding agencies (e.g. ACC) must understand it and have systems in place for it to be able to be used. It is difficult for a company to initiate clinical trials as there is a potential ethical issue around the company wanting to sell the product to the patient.
- Data privacy issues are still not easily resolved when tracking or measuring items related to a person.
- Lack of exposure to proven technology in the international market means New Zealand is behind in terms of adoption.
- Costs need to be low to compete with traditional methods.
- Integrating RAS into a section of the process/ workflow can mean some information may be lost, potentially hiding future risks or opportunities in the patient's care.

Predicted RAS direction within Healthcare over the next 5-20 years

	0-5 Years	5-10 Years	10-20 Years
In-Patient	• Surgery performed with soft robotics • Assistive patient care	• Patient surgery simulation • Supply chain robotics e.g. laundry	• RAS smart patient interpretation providing real-time feedback on changes in condition and treatment.
Out-Patient Care	• Rehabilitation exoskeletons. • Companionship and medicine adherence	• Non-invasive mechanistic diagnostics with RAS. • Commercial robotic prosthetic hand control via EMG signals • Elderly care movement assistance (inc showering) • Personalised companionship robots	• Full feedback control prosthetics (i.e. feedback of touch to human) • Elderly assistance (inc showering) • Rural patient consultation

Industry Recommendations

- **Create an initiative which enables clinicians and RAS developers to understand the current problems in healthcare that could be effectively addressed by RAS technology.**
- **Enable better processes for clinical trials of new RAS products in New Zealand.**

Many New Zealand-based companies are disconnected from the worldwide developments and advancements in RAS technology. Improved guidance around RAS innovations in the key economic sectors of New Zealand could significantly help improve existing productivity levels.

RAS technology may need to be adapted before being used in New Zealand, in order to be relevant to our workplaces. Making support and work streams in New Zealand easily accessible will minimise the risk of integration failing.

- **Improve guidance and support understanding of global RAS innovations for key economic sectors of New Zealand**

A key driver to technology adoption is competition. New Zealand's small, isolated markets tend to have low competition levels when compared to other countries. As a result, there is little incentive in some sectors for firms to understand the potential benefits of adopting RAS.

- **Improve developers' ability to demonstrate their RAS technology and ROI**

New Zealand-based developers need to have the foresight to develop RAS solutions applicable to the broader international market and global issues. New Zealand-based RAS companies who focus on developing products for the small New Zealand market tend to only receive limited and non-sustainable government funding. In addition, the challenges around end-user market adoption in New Zealand significantly reduces potential sources of revenue. As a result, these New Zealand-focused companies typically have a short lifespan.

RAS companies who have a domestic market to support them during their development prior to entering the international market tend to be more successful in actually reaching the international stage.

- **New Zealand-based RAS developers should target an international market from day one, with a solid New Zealand market to support them through their growth phase**

In addition to the challenges to reach the international market, limited Venture Capital (VC) investment is commonly cited by New Zealand-based RAS developers as a key restriction to the development of new products or companies.

Compared with more developed nations such as the United States and the United Kingdom, New Zealand receives anywhere from 2-60 times less VC than their counterparts there. As a result, New Zealand-based RAS companies are required to be extremely innovative to compete with companies from those nations which receive significantly more VC investment during their growth (e.g. USD$ 1 million vs USD$10 million).

"We need fast-growing firms operating in a healthy, well-capitalised start-up ecosystem. But there are large gaps in the early-stage capital markets, especially for series A and B capital rounds, and no new firm has listed on the public exchange for a number of years. Many of these high-growth firms are forced to seek capital abroad and can end up leaving our shores prematurely as a consequence."

Growing Innovative Industries in NZ, 2019

As New Zealand RAS companies build a reputation, more VC investors will look to New Zealand to invest and help build the RAS ecosystem here. International VC investment will slowly grow as our reputation builds and becomes more globally visible. A strong, internationally-recognised RAS ecosystem will significantly accelerate this process.

- **Improve the visibility of New Zealand's RAS capability to help improve VC investment**

The four main sectors in which people were most optimistic about potential RAS development and investment are: food and beverage (31%), health and biosciences (25%), manufacturing (6%), and other (25%).

Investment partners bring networks, experience and skills to the company which can help accelerate growth. In particular, international investment can bring invaluable knowledge and capabilities to a company which may not be available in New Zealand.

According to a recent TIN report, the majority of New Zealand tech investment comes from New Zealand, Australia, and North American-based investors (at 29.1%, 26%, and 22%, respectively). The investment by these relatively close networks provides an important stepping stone for New Zealand tech companies to reach the international market.

- **Improve commercialisation guidance and support**

Many New Zealand RAS companies believe there is a lack of support and guidance for commercialisation of technology and reaching the international market. The majority of younger companies spoken to felt there was little support and experience offered, particularly during the growth stage of a company (5-10 employees). As a result, these companies were going to international VCs for guidance and support. There is a need for improved access to guidance and support for New Zealand-based RAS companies during their commercialisation and globalisation phases.

- **Provide early support for RAS companies to reach international markets**

Some companies had little experience and support to access international markets. Although New Zealand Trade and Enterprise (NZTE) exists for this purpose, companies typically found NZTE support only occurred once they had already achieved a position in international markets, rendering this service partially redundant. By envisaging the potential of New Zealand RAS technology internationally, NTZE could provide an earlier support and foster a faster pathway to global growth.

- **Create an industry body and network to support the development of New Zealand-based RAS companies**

Currently, New Zealand-based RAS developers are not recognised collectively by an industry body or even by the EngineeringNZ subsets. Creating a RAS industry body and network is strongly recommended. This could be used to facilitate networking, transfer ideas across sectors in which RAS is applied, and help guide and support other New Zealand-based RAS companies to become internationally competitive.

The lack of a dedicated industry body disconnects industry from relevant developments around the RAS technology they use. The development of any RAS involves multiple disciplines of expertise to deploy. It is highly unusual for a company to have all the expertise required at hand to develop the product immediately.

Companies may typically upskill in-house, or hire new staff or expert consultants to gain the correct skill sets, or in order to protect any potential IP or competitive advantage the RAS product provides. However, developing RAS in this way is very challenging, time inefficient, requires repetitive knowledge building, and reduces any potential 'first to global market' advantage. If a network existed where companies could comfortably and securely go to share expertise and resources, this would significantly reduce R&D development duplication, and improve the efficiency and potentially quality of the developed RAS product.

Many companies expressed their desire for more industry networking, particularly for technical product development.

Cluster network

With more than 50% of RAS stakeholders based in Auckland, a localised cluster network could be formed there first, with regional clusters subsequently developed. Such a cluster would prove to be economically beneficial for each local region, as observed globally, and could be potentially initially funded from regional development funds. Auckland could also serve as a base for international visitors, once travel borders reopen.

- **Maintain New Zealand's brand reputation for high-quality products**

Over the past five years New Zealand has been ranked number one in the world for ease of doing business.

The "New Zealand brand" provides New Zealand companies with a reputation for providing high-quality, ethical and environmentally-friendly products. This reputation extends to RAS products, with many RAS companies stating that this "New Zealand brand" reputation is one of their selling points. Maintaining and building this reputation is important in developing the RAS ecosystem in New Zealand, and using it as a selling point.

- **Promote New Zealand as an excellent RAS testing environment**

New Zealand's advanced, resilient, but small economy offers a great opportunity for international companies to test new products and methods in a mature test environment.

Did you know?

Many companies test many of their products here before rolling them out globally. Examples include:

New Zealand was the first country in the world to test EFTPOS

Facebook and LinkedIn test new web features in New Zealand before they are rolled out to the rest of the world.

Ports of Auckland was the first to use Autonomous Straddle Carriers (A-STRAD) of shipping containers in side-by-side operation of manually operated carriers

The Google Loon project was first tested in Canterbury, providing internet access to remote communities through stratosphere balloons

Dominos first tested their UGV pizza delivery unit in New Zealand

Interconnectivity

Due to New Zealand's small scale and connected culture, communication with key Government and regulatory officials is relatively easy, compared with many other nations. As a result, companies can easily discuss the regulations around their technology and how it can be adapted.

Rocket Lab stated they would launch from anywhere in the world, but they started in New Zealand because they could talk directly to Minister of Parliament, Steven Joyce, about adjusting regulations.

Additionally, this ease of communication enables the relatively simple establishment of multi-organisation and multi-domain relationships required for significant collaboration gains. This is demonstrated by Xero, the first online-only accounting package to connect to all the banks and the tax system (IRD) in New Zealand, thus proving the feasibility of their system.

Regulatory environment

New Zealand's relatively light regulatory environment has proven to be very beneficial for the testing of RAS. In many cases the regulations do not specifically ban the usage of RAS and only require a simple exemption to be filed before use. However, creating a regulatory framework around the use of UGV (detailed in page 37) and UAV (particularly around Beyond Line Of Sight (BLOS) flight) will strengthen the benefits of RAS testing in New Zealand and reduce the challenges faced by the companies in this space.

Geographic advantage

Testing within New Zealand develops the economy, brings talent to New Zealand and enables better connectivity, exposure, and potentially earlier adoption of modern RAS technology. Future efforts should focus on encouraging further RAS testing through the advertisement of the unique benefits of working in New Zealand.

New Zealand has a distinct range of terrains and environmental conditions which enables all kinds of robust outdoor RAS testing to be performed. Although not currently fully realised, this creates a considerable opportunity for RAS developments in agriculture, horticulture, outdoor logistics and aerospace.

Because New Zealand's conditions run counter-seasonal to the Northern Hemisphere, this enables RAS product testing to be performed in New Zealand during their "off season" enabling faster product development and quicker deployment for RAS companies.

Education & Skills

The New Zealand education system is vital to providing people with the right skills for developing and adopting future RAS innovations, and ultimately improving economic outcomes.

This includes the development of initial interest in and perspectives on RAS technology, right through to the technical fundamentals which drives RAS technology. In New Zealand it appears that interest and understanding of RAS has been growing rapidly in the past decade, driven by the global growth of RAS.

- **Further support existing primary and secondary school robotics programmes to make them more accessible to a wider range of schools**

The introduction of robotics at primary and secondary school levels of education is extremely beneficial to developing an individual's capability around STEM, and also their general interest in this area. The hands-on application and understanding of such systems also helps improve the general public's social acceptance of RAS. At present such programmes are currently limited to schools which can afford the robotics kits and have the capacity to run these school programmes. This limits the breadth of potential STEM growth within New Zealand's education system.

- **Promote New Zealand's RAS ecosystem and capabilities to tertiary students to create a pipeline to New Zealand RAS industries**
- **Create better tertiary education and industry hand-over through improved parallel work streams for graduating students**

Industry believes the fundamental skills tertiary institutes provide is satisfactory, and many expressed the need for more exposure to industry work realities around health and safety, project management, product development and teamwork. Currently, industry has taken the role of educating new graduates in the real world needs and practicalities and business acumen around RAS development, so they can become productive employees.

Industry feels that an improved internship programme and/or parallel industry and university work stream may enable students to more quickly contribute to the businesses growth. Such a programme should enable industry to better set pathways for new graduates into their business.

- **Improve upskilling and retraining opportunities for employees negatively affected by RAS integration**

As RAS is integrated into a workplace the tasks required of the employees may change, with some studies predicting up to 75% of labouring jobs in New Zealand will be automated.

When asked about upskilling current employees, many RAS industry developers stated that they typically provided in-house training or allowed the employee to research online any new products or methods. As the pace of industry is relatively fast, formal upskilling (through tertiary institute courses) is far too slow and it is easier for industry to either employ new staff with the required skills or allow a current employee to upskill in certain areas through online learning.

Studies have shown that creating individuals with more specialised skills enables a country to be an earlier adopter of new RAS methods.

Finding and keeping individuals with these specialised skills is difficult in a small New Zealand market, due to the small customer base, lower profits, and ultimately lower salary budgets. Improving access to foreign skills and incentives to New Zealand returnees would be beneficial. In addition, hiring migrants has shown to encourage a company to create new products and enter new export markets.

Some employees are typically shifted into roles which machines cannot do, such as managing people, applying expertise, and communicating. As a result, if upskilling or retraining into these roles is not undertaken, there will be an excess of lower skilled labour, leading to further inequality in New Zealand. An effective upskilling and retraining programme for these employees is required to mitigate these potential increases in inequality.

Government

New Zealand needs to embrace RAS through increased adoption and deploying faster technological change. A more rapid adoption of RAS will enable opportunities to improve the living standards and wellbeing of many New Zealanders.

The Government plays a key role in supporting New Zealand's RAS development and adoption through the policies, institutions, and investment, which reduce the barriers to involvement. This includes evolving and innovating policies which help support commercialisation, legal and ethical matters around RAS usage, retraining and upskilling, and regulatory standards — while also creating policies that support early RAS adoption and investment, and provide the digital infrastructure needed to support RAS usage. The idea of RAS in New Zealand is mentioned in many reports but there has been no clear initiative or focus to address the issues .

In 2018, government R&D expenditure was only 47% (NZD $784 million) of the OECD average (0.28% vs. 0.59% of GDP). Main Science and Technology Indicators (MSTI), significantly underperforming the OECD. The money invested has been primarily focused around primary industries (35%), the environment (33%), and manufacturing (12%). This has resulted in a few developments around RAS in horticulture, forestry, and manufacturing. However, there have been very few multi-year initiatives, limiting their ability to establish change.

- **Adjust policy around the R&D tax incentive to enable successful RAS R&D products to reach a commercially viable level.**

New Zealand's two main R&D tax incentive programmes are the R&D tax credit system and the R&D loss tax credit system. Consultation with industry showed that these R&D tax incentives were not a driver for R&D, only something which made the process easier. In addition, many stakeholders found that the incentive only supported the initial prototyping of RAS and not the development of the prototype into a commercially viable product. The cessation of funding once the fundamental R&D is performed significantly constrains the ability for the successful R&D to actually reach the market.

- **Callaghan Innovation and the RAS industry work together on capability building in development and integration.**

Callaghan Innovation has been shown to support innovation well in New Zealand by providing technology development services, expert guidance and skills, and innovation grants. Almost all of the RAS companies consulted with used Callaghan Innovation's services in some manner, with many working on R&D projects with them or using the student internship programme on R&D project development. Callaghan Innovation also provides some education towards technology adoption with their Emerging Technology workshops and technology trial programmes.

As RAS technology is becoming more commonplace, and companies are becoming experts in integrating such technology into a workplace, the integration of RAS is becoming more of an industry service than a government R&D project.

In NZ there are currently estimated to be over 42 capable companies integrating RAS technology into a workplace. Some companies have reported 'competing' with Callaghan Innovation for RAS projects, as Callaghan deemed it as an R&D project and not something that industry could provide. This highlights how rapidly RAS technology is becoming commonplace, and the need for Callaghan Innovation to better understand the capabilities of emerging RAS. Deploy a range of more modern RAS systems in the workplace, such as mobile RAS.

RAS technology and its associated capabilities are developing rapidly, and so are the number of potential application areas. In order for New Zealand to best utilise RAS developments whilst still protecting its citizens, the New Zealand regulatory environment needs to adapt and modernise. New Zealand organisations in general have a reputation for being flexible and adaptive to regulations. Our efficient and effective legislative process in combination with our relatively small and agile size has resulted in New Zealand being a good testbed for many overseas companies.

- **Create a defined regulatory framework around the usage of UGVs in New Zealand.**

UGV usage in New Zealand appears to have mixed results. Currently, any vehicle on a public road must meet the New Zealand Land Transport regulations, except where they have an exemption, which is commonly granted for UGVs. Conveniently, this legislation also does not explicitly require the vehicle to have a driver present for it to be used. To encourage further UGV testing, New Zealand has improved the framework around applying for the required exemption. However, the integration of a tested system appears to be more difficult. From consultation with the Ministry of Transport they were met with a lack of Government direction. Government consultation being required in the development process significantly reduces the speed of development. Further work is needed to better understand how a fully autonomous vehicle (not based on an exemption within automotive standards) can fit into the regulation environment.

- **Improve regulation and standards authorities' understanding of how RAS standards may deviate from manual labour standards.**

RAS developers are facing barriers in terms of the standards around a process being different for RAS methodologies, compared to traditional manual labour methods. RAS was typically required to perform better than that achieved by a human, or to adhere to standards developed for human actions. In some cases, these more stringent and unreasonable requirements on RAS resulted in the RAS being financially unviable.

Overall, there is a need to understand why existing standards are in place for all processes where RAS may potentially be used, and better adapt these for the use of new RAS. Once a more reasonable regulatory framework is established, then any potential benefits can be realised.

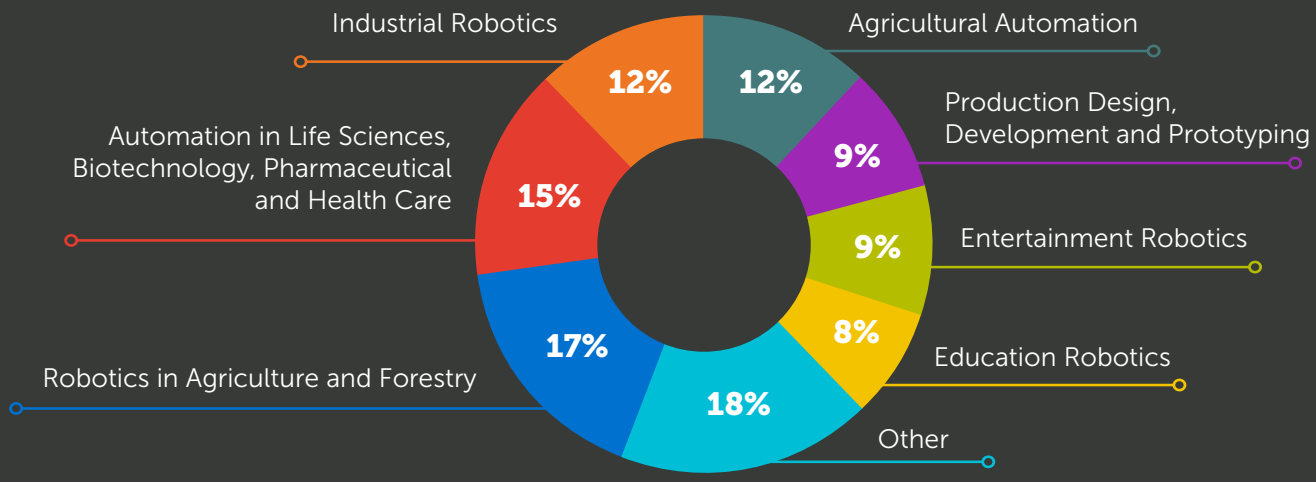
Research

New Zealand's RAS research environment is a growing field with currently over 70 researchers across the country, with representatives at almost every research institute. Since 2005, the research publication output around RAS technology has been growing steadily, consistently at around 75-80 publications a year.

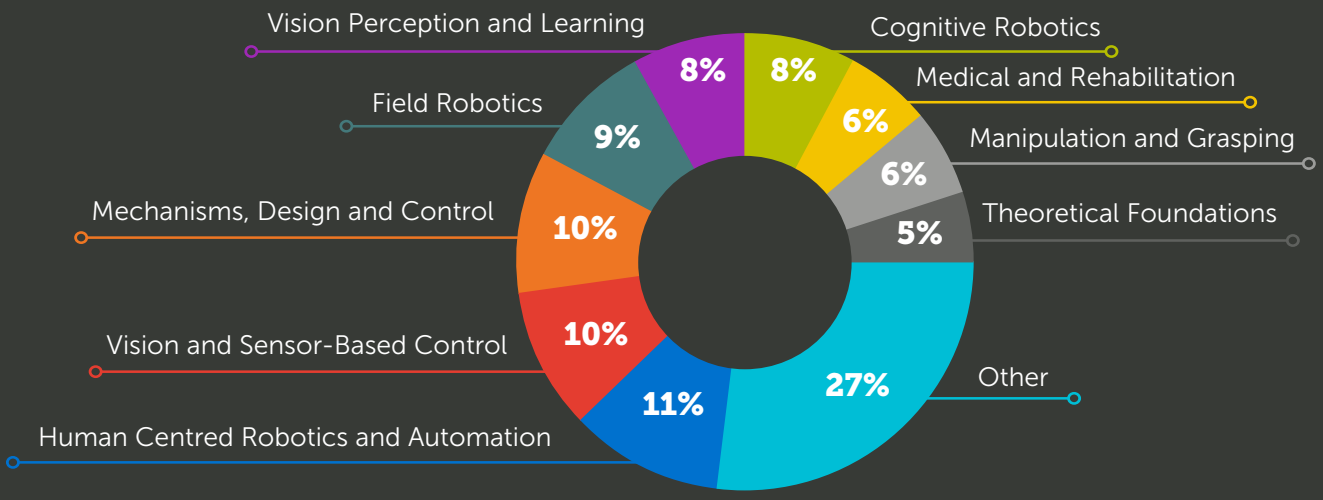
The highest RAS related research outputs came from the University of Auckland (31%), the University of Canterbury (20%), and Massey University (11%).

To further understand our capabilities in this area a survey was sent out to all identified researchers regarding their research application areas and fundamental RAS research areas. The results are as follows:

New Zealand Robotics Researchers – Application Areas



New Zealand Robotics Researchers – Fundamental Areas



The strengths in these areas are likely driven by the issues seen in the researchers' environment and the areas in which New Zealand government funding is most readily accessible.

- **Fund RAS research projects for longer, with increased industry involvement, to create commercially-viable RAS.**

There are multiple broad-scoped Government R&D funding schemes which RAS development can apply to. However, the limited funding offered by these schemes applies across all STEM research, is highly competitive, and typically results in low funding amounts and the number of projects funded. To date, it is estimated that over NZD $36 million in government funding (0.3% of all MBIE funding since 2005) has directly funded RAS related research.

When compared to the OECD average the total amount of R&D expenditure is only 57% of the OECD average (1.37% vs. 2.38% of GDP in 2018). This appears to be the result of significantly lower business (0.75% vs. 1.49%) and Government (0.28% vs. 0.59%) R&D expenditure.

This issue does appear to be a focus area of future policy, aiming to raise overall GDP R&D expenditure by 2% by 2027, particularly with stronger government support for industry research.

As the limited funding provided is highly competitive across all STEM fields, researchers spend a lot of time and effort competing for their next funding stream, and not performing actual research.

Researchers and industry expressed concerns that current research is not funded to a commercial level. Although some bids now require a description of the intended commercialisation pathway, the actual resulting concept typically only functions to 80% or 90% of where it needs to be for a commercially viable product.

The remaining 10 or 20% addresses the real-world application and business issues of the RAS technology, and requires strong industry partnerships. This remaining part of the development process is currently not funded as the funding rounds typically end too quickly, and the project is abandoned. A system where projects are funded for longer with increased industry involvement near the end may prove to be more beneficial in creating commercially viable research outcomes.

Research

- **Revise RAS research organisation priorities and Key Performance Indicators (KPIs) around commercial outcomes of research**

The percentage of research projects that become commercialised is generally considered to be poor. This is likely the result of multiple factors:

- Academics and universities KPIs are based strongly around publication output and not commercialised research output. As a result, a lot of time is spent writing papers and not testing ideas in the 'real world'. This can be seen in New Zealand's relatively high ratio of publications to Government R&D expenditure, but a very low number of start-ups and patents, in relation to the OECD average.
- Although commercialisation groups at research institutes exist, the pathways are not always clear and supported.
- Issues around Intellectual Property (IP) management exist, where the university typically wants a share, which, as a result restricts industry development.
- Researchers may have a poor understanding of commercial realities purely due to this not being their focus area. As a result, better collaboration with those who understand this space may prove beneficial.

These factors come back to the key priorities of a research institute not necessarily being aligned with creating commercial outcomes. A revision of these priorities and their KPIs is required to improve commercial outcomes.

- **Investigate methods to better support SMEs to invest in R&D with RAS researchers**

Through consultation with RAS stakeholders, it appears that New Zealand businesses typically only invest their money into research which will provide guaranteed quick results.

Overseas examples have shown that this does not need to be the case, and that long-term research which may, or may not, be commercialised are still beneficial. This is likely the result of New Zealand being made up of many SMEs which have much smaller resources and may think less strategically about the long-term benefits of RAS.

New Zealand businesses invest significantly less into R&D than the OECD average. As New Zealand does not have multiple large, stable companies that can lead innovation, there is a need for a mechanism enabling SMEs to better invest in R&D, while not using up all of their resources. Although ideally the R&D Tax incentive and Partnership Scheme should help with this, currently the funding is still too limited.

- **Investigate forming an organisation which facilitates the networking and collaboration between all RAS stakeholders across New Zealand**

There appears to be a disconnect between the developments in industry, and research performed by academics, reducing the cohesion across the overall RAS ecosystem.

Many RAS industry stakeholders are unaware of the developments and capabilities of New Zealand researchers and other RAS industry stakeholders in other sectors.

This fragmentation results in repeated work, under-used RAS resources and expertise, and ultimately, inefficient development of RAS. There is a lack of focus on larger RAS goals beneficial for the New Zealand industry and its productivity.

Fragmentation is partially driven by the geographic spread of the stakeholders across New Zealand with clusters around Auckland, Waikato, and Christchurch. An organisation which facilitates the networking between all New Zealand RAS stakeholders would prove to be very beneficial to New Zealand RAS development. Some industry stakeholders have found it difficult to collaborate with researchers due to pathways and structures being unclear. This organisation could also help form these processes, furthering collaboration within the RAS ecosystem.

- **Further investigate methods in which RAS industry and researcher stakeholders can collaborate with varying timelines e.g. through multi-phase projects**

There have been some successful collaborations within the RAS ecosystem, but these largely appear to be driven by key individuals pushing against the norm, rather than a supportive collaboration ecosystem.

Case studies of successful collaborations, and the potential benefits of the collaboration for each stakeholder are needed to demonstrate successful involvement. Due to the very different drivers between the RAS industry and researchers, there is a strong misalignment of timelines. Industry typically wants a functioning prototype as fast as possible, whereas researchers may want to perform more cutting-edge methods, taking a longer-term view on the problem to be solved. This results in the need for some sort of compromise of outcomes. This could be solved by creating multi-phase collaboration projects. The first phase creates a functioning prototype, and the second phase looks at a more long-term solution, all while still having industry collaboration.

Many find it difficult to make time for collaboration with industry between teaching, publishing and applying for their next funding. Industry collaboration is not typically seen as a research organisation's KPI, so this becomes a lower priority.

Culture & Diversity

The diversity of gender and ethnicity around RAS development is generally poor. Significant benefits can be achieved through a diverse workforce — they are 5% more likely to outperform non-diverse workplaces. Gender diversity is relatively the same as the unequal balance seen in all STEM fields. Racial diversity appears to be stronger with many Asian and Indian ethnicities. However, the representation of Māori and Pasifika is almost non-existent. The majority of RAS stakeholders consulted stated that they had no Māori or Pasifika individuals employed. Many still had culturally diverse workplaces with a diverse range of international cultures.

It was believed that the low number of Māori and Pasifika individuals was due to the lack of visible opportunities for these individuals to acquire RAS skills and then seek work in the RAS field. Currently some direct involvement was identified at the research level into RAS, but there was almost no involvement observed at the industry level.

- **Establish a single organisation to promote the benefits and capabilities of RAS**
- **Promote real-world examples of capabilities to a diverse range of people**
- **Investigate the feasibility to foster honest conversations about access to RAS**
- **Open up opportunities to promote RAS to women**

It is estimated that women only make up 23% of New Zealand's tech sector, and men are five times more likely to study engineering. These trends were also strongly observed when consulting with RAS stakeholders, with a very small population of women working in the RAS field. This echoes the wider STEM ecosystem, where the involvement of women in STEM is a larger societal issue. More needs to be done to create a safe and welcoming environment for women in STEM, and in the RAS field.

No specific initiative for improving the presence of women in RAS could be identified.

Culture & Diversity

women only make up

23%

of New Zealand's tech sector

only

13%

being employed as engineers

Many initiatives exist to help improve the presence of women in STEM and tech, but there has been limited success to date, with an estimated number of only 13% being employed as engineers. The number of secondary enrolments by women and girls in RAS-related fields is steadily declining.

Many RAS stakeholders believed that this problem started in primary and secondary schools, where the interest in potential future career areas develop. School programmes such as VEX Robotics, FIRST Robotics, OneWorld and RoboCup should aid this, but their influence on women entering the RAS field still appears to be limited. Women are still considerably underrepresented within the RAS field, and future work should focus on supporting improved pathways for women to get into, and stay in, the RAS field.

- **Develop and expand existing Māori and Pasifika initiatives alongside Māori and Pasifika developers**

Although some initiatives exist, such as RoboPā, funded by MBIE's Curious Minds, a programme which integrates 20 Vex robotics kits into Wānanga across the North Island, and Pasifika in IT, the long-term effect of these initiatives is still yet to be observed. It is likely that these initiatives will help support the number of Māori and Pasifika people entering the RAS field, and should be continued to be supported and expanded.

Involve Māori in the development process from inception to delivery

There is a strong opportunity to improve Māori and Pasifika representation and better incorporate the traditional knowledge and methods of Māori culture, in terms of developing more sustainable RAS solutions. Māori offer significant value to the development of RAS in New Zealand. In order to better utilise this knowledge, people and resources, there needs to be greater collaboration with Māori in the development process and when considering the ethical use of RAS.

Future initiatives should focus on improving the understanding of potential involvement of Māori in the RAS development through a series of case studies featuring their involvement.

Māori own approximately 10% of New Zealand's total agriculture, forestry and fishing assets, and have a significant role in guiding the technological development in these sectors.

"Māori take a gentler approach to forestry.... not taking every tree, but taking this year a few, and some trees the next year. That way there are always trees on the land... Those trees will be worth a lot of money individually, but you're doing very little damage to the environment in doing so."

- Richard Parker SCION

FUTURE OPPORTUNITIES

As RAS technology develops there is room for significant uptake in RAS usage across many sectors. We recommend the following measures for increased RAS development and usage in New Zealand:

Agriculture and Aquaculture

- Develop demonstration farms with associated testing facilities (similar to overseas 'smart farms' that are:
  - accessible to research institutes and startups to test during R&D phases
  - accessible to farmers/growers to see tech in action and offer their feedback
  - accessible to interested parties (including media) to show RAS in operation
- Support and undertake large, statistically significant studies which prove the benefits and business relevance of new RAS technologies to each sector
- Current supporting initiatives: Agritech ITP (NZ Govt), Extension Services Model (MPI), Farm 2050 (Global Agritech), NZ Fieldays (NZNFS)

Healthcare

- Develop a cross-working initiative between clinicians and RAS developers to see where the pain points are, and potential RAS solutions that focus on assisting clinicians in their day-to-day practices
- Establish more effective clinical trial processes to test new RAS developments
- Current supporting initiatives: MedTech CoRE and CMDT, ECLI Service (NZ Govt)

Horticulture and Forestry

- Investigate the creation of a growers RAS testing network providing a framework for RAS developers and end-users to test local and international products
- Join existing efforts in horticulture and forestry upskilling using RAS technologies to attract and train students on the job
- Ensure closer working relationships between forestry industry and RAS developers to understand pain points and collaborate on potential solutions
- Work with the horticulture industry to develop tailored products using and refining existing AI, machine learning algorithms and sensors created by New Zealand researchers
- As vertical and greenhouse farming becomes more established in NZ, offering opportunities for RAS developers to develop internationally-applicable products and test them onsite
- Current supporting initiatives: Agritech ITP (NZ Govt), Extension Services Model (MPI), Farm 2050 (Global Agritech), Western Growers (Agritech NZ), One billion trees programme (MPI), NZ Fieldays (NZNFS)

Manufacturing

- Focus on improving SME access to RAS, through lower-cost, flexible automation, and collaborating with manufacturers to adapt New Zealand RAS solutions for more complex manufacturing environments, like meat processing, and food and beverage processing
- Current supporting initiatives: Industry 4.0 Hub (CI), Cobot trial programme (CI)

Consumer and Professional Services

- Accelerate Unmanned Aerial Vehicle (UAV) integration through faster development of commercial regulations, particularly in Beyond Line of Sight (BLOS) operations
- Create more opportunities for RAS developers to demonstrate their products to a wider audience at targeted industry events
- Current supporting initiatives: CRRF (NZTE), Service sector RAS support business, Autonomous Aircraft Taking Flights (MBIE)

Construction and Infrastructure

- Provide funding for targeted RAS research and development to help address the major skills shortage
- Showcase international RAS developments, and actively improve regulatory and consenting processes for new methods

Trans-Tasman Collaboration

- Establish an Australasian industry and research network, which will then create a trans-Tasman register of RAS capabilities, including tertiary research teams, commercial developments and organisations. This network could then:
  - Host a regular trans-Tasman RAS industry conference to showcase developments
  - Collect RAS case studies from across Australasia
  - Market and promote Australasian RAS capabilities locally and globally, with the aim of attracting RAS practitioners from around the world
  - Share standards around design and coding, and facilitate better sharing of solutions
  - Share local and international networks to grow RAS markets and build more effective international partnerships
  - Work with Government and agencies including CAA to share UAV testing and development knowledge
- Specific potential initiatives include:
  - Autonomous air freight or shipping between New Zealand and Australia
  - An international challenge around seafood harvesting
  - Search and Rescue operations
  - Mining in Australia, and forestry in New Zealand, which have challenging environmental conditions

New Zealand has the opportunity to become a world leader in specific areas of RAS development, supported by a growing research and industry ecosystem. New Zealand's regulatory environment has proven beneficial for the testing of RAS, and by building a collaborative trans-Tasman network, we can improve productivity in sectors with challenging environmental conditions.

COVID-19 recovery

COVID-19 recovery is subject to ongoing mutations of the virus. COVID-19 recovery relies on high vaccination rates within the New Zealand population. At this stage it is not possible to gain an accurate prediction into what recovery looks like.

Trans-Tasman Collaboration

Trans-Tasman collaboration relies largely on how Australia recovers from COVID-19. At present the Trans-Tasman travel bubble is closed, which significantly limits the potential for collaboration.

Australia and New Zealand have a well-known history of collaborating, forming many Trans-Tasman partnerships which have improved trade and immigration between the countries. Both countries share similar time zones, and many industry and government policies, laws, and regulation regimes which further improves trade. Within both countries the interest, development, and usage of RAS is growing significantly.

A multinational collaboration can bring the resources and insights from different nations together, improving their overall international competitiveness. Such a collaboration between New Zealand and Australia could be significantly beneficial for both nations' RAS developments.

Conclusion

This Roadmap provides the first quantification of the presence of RAS in New Zealand, across industry, government, and research organisations, identifying over 128 industry developers or integrators, and conservatively estimating over 350 users.

The future looks bright. Due to the strong existing presence of the RAS industry, New Zealand has a significant opportunity to move forward and create a more cohesive ecosystem which drives New Zealand-based RAS company growth, and the adoption of RAS.

Alongside the implementation of the recommendations outlined, New Zealand is in a great position to become a world leader in specific areas of RAS development, due to the existing supporting initiatives, research strengths, current industry presence, and unique regulatory environment.

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